

APPLICATION  
FOR  
UNITED STATES LETTERS PATENT

TITLE: CARDIO-PULMONARY RESUSCITATION DEVICE WITH  
FEEDBACK FROM MEASUREMENT OF PULSE AND/OR  
BLOOD OXYGENATION

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5      CARDIO-PULMONARY RESUSCITATION DEVICE WITH FEEDBACK FROM  
         MEASUREMENT OF PULSE AND/OR BLOOD OXYGENATION

Technical Field

         This invention relates to devices for assisting cardiac resuscitation.

10      Relationship to Other Applications

         The following copending applications are incorporated by reference: U.S. Serial  
No. 10/370,036, filed on February 19, 2003; U.S. Serial No. 09/794,320, filed on  
February 27, 2001; U.S. Serial No. 10/421,652, filed on April 23, 2003; U.S. Serial No.  
15      09/846,673, filed on May 1, 2001; and U.S. Serial No. 10/441,933, filed on May 20,  
2003.

Background

         This invention relates to the field of cardiac resuscitation, and in particular to  
20      devices for assisting rescuers in performing cardio-pulmonary resuscitation (CPR). CPR  
is used to mechanically support circulation in subjects with cardiac arrest. Although, the  
American Heart Association (AHA) has proposed guidelines for CPR, the effectiveness  
of this intervention is difficult to actively assess as it is performed. The ZOLL Medical  
AED Plus system provides rescuers with valuable feedback on compression rate  
25      (metronome) and depth (audible prompts) to promote the proper CPR methodology.

Summary

         I have discovered that improved feedback can be provided to a rescuer providing  
CPR by providing adjustments to the metronome and additional audible prompts based  
30      on the effectiveness of the CPR on the victim's circulation as measured by pulse rate and  
SpO2 from oximetry.

         In a first aspect, the invention features an apparatus for assisting a rescuer in  
performing CPR on a victim. The apparatus comprises at least one of a pulse sensor for  
measuring the pulse rate of the victim and an SpO2 sensor for measuring blood

oxygenation; electronics for processing the output of the sensor or sensors and determining one or more actions that the rescuer should perform to improve the CPR being performed; and a prompting device for conveying the one or more actions to the rescuer.

5 Preferred implementations of this aspect of the invention may incorporate one or more of the following. The apparatus may further comprise an external defibrillator. The apparatus may comprise an SpO2 sensor but not a pulse sensor. The apparatus may comprise a pulse sensor but not an SpO2 sensor. The apparatus may further comprise a chest compression sensor. The chest compression sensor may be an accelerometer. The  
10 electronics may be provided with information on compression rate. The compression rate may be sensed or derived from a chest compression sensor. The prompting device may comprise a device that conveys a desired rate of compression to the rescuer. The device that conveys a desired rate of compression to the rescuer may comprise a metronome. The prompting device may comprise a speaker and associated electronics for conveying  
15 audible instructions. The electronics may comprise a digital computer executing computer software. The electronics may compare compression rate to a desired CPR rate. The electronics may compare a measured level of blood oxygenation to a desired level. The electronics may provide a prompt instructing the rescuer to release from the chest during CPR delivery if the sensors indicate that the rescuer is not adequately  
20 releasing from the chest. The electronics may provide a prompt to the user to press harder if the pulse sensor indicates that there is no measured pulse rate. The electronics may provide a prompt to press harder if the sensor indicate that a pulse is detected but SpO2 is below a defined level. The electronics may provide a prompt to increase compression rate if the sensors indicate that a pulse is detected, that chest compressions  
25 are at a defined level, and that SpO2 is still below a defined level. The electronics may provide prompts to increase compression rate and compression pressure simultaneously based on measurements from sensors. The electronics may provide a prompt for the user to interrupt chest compressions to give one or more breaths. The prompt to give one or breaths may be issued when sensor measurements show that blood circulation is  
30 occurring and that the cause of a falling SpO2 level may be an increase in metabolism. The electronics may provide a prompt to continue CPR without interruption for

breathing based on SpO2 levels that were above a given threshold so as to ensure that there would be no break in circulation when blood oxygen levels remained high and ventilation was not yet required.

Other features and advantages of the invention will be apparent from the  
5 following detailed description, and from the drawings and claims.

### Brief Description of the Drawings

FIG. 1 is a diagrammatic view of a rescuer providing CPR to a victim with the aid of an implementation of the invention.

10 FIG. 2 is a block diagram of an implementation of the invention.

FIG. 3 is a flow chart of the operation of an implementation of the invention.

### Detailed Description

There are a great many possible implementations of the invention, too many to  
15 describe herein. Some possible implementations that are presently preferred are described below. It cannot be emphasized too strongly, however, that these are descriptions of implementations of the invention, and not descriptions of the invention, which is not limited to the detailed implementations described in this section but is described in broader terms in the claims.

20 The descriptions below are more than sufficient for one skilled in the art to construct the disclosed implementations. Unless otherwise mentioned, the processes and manufacturing methods referred to are ones known by those working in the art

FIGS. 1-2 show an AED implementation of the invention that can measure CPR rate and depth with an accelerometer, and SpO2 and pulse rate with an oximeter probe  
25 (FIG. 1). These measures are provided as inputs to a software module, which assesses whether the CPR is producing adequate pulse rate and oxygenation (FIG. 2). The SpO2 sensor can be located in various locations, e.g., on the finger to provide measurements on the peripheral circulation and/or on the forehead to reflect cerebral circulation.

The user is initially prompted with the use of a metronome (i.e., a rate indicating  
30 prompt) and audible instructional prompts to perform CPR optimally according to AHA guidelines (100 cpm, 1.5 – 2.0 inch compression). Based on the current compression rate,

compression depth, SpO2 measurement, and pulse rate, the compression rate and compression depth can be altered from the recommended guideline via the metronome and voice prompts to improve circulation. For example, the feedback control system via the AED metronome and audible prompts can operate with the user in the following ways based on the state of the CPR and the state of the patient (FIG. 3):

1. If a pulse rate is measured that matches the CPR rate and the SpO2 has reached a defined level, CPR may be considered adequate and no changes to the metronome or additional voice prompts may be required.

2. The user may be prompted to release the chest if the CPR system has determined that the chest is not being completely released at the end of each compression.

3. If there is no pulse rate from the oximeter, the user may be prompted to pressure harder until the pulse rate is detected.

4. If there is a detected pulse rate and the SpO2 level has not reached a defined level, the user may be prompted to press harder to increased in the oxygen saturation.

5. If the increase in compression depth meets a safe maximum and does not achieve the desired SpO2 level (in item 3), the metronome rate can be increased to a safe maximum rate to increase saturation.

6. Based on the current state of the compression rate and depth and the pulse rate and SpO2, both the metronome rate and the compression prompts can be used simultaneously to more quickly move to a desired operating point.

7. The user may be prompted to continue CPR without interruption for breathing based on SpO2 levels that were above a given threshold. This would ensure that there would be no break in circulation when blood oxygen levels remained high and ventilation was not yet required. There is literature which indicates that within an initial period following collapse there is sufficient oxygen reserve in the blood that ventilation is not necessary and CPR should not be interrupted. Monitoring the SpO2 and guiding the user through audible prompts would suppress breathing and direct uninterrupted CPR.

The feedback system may, also, be used to prompt the rescuer to deliver rescue breathing when chest compression depth and rate are appropriate but arterial blood oxygen saturation is falling from a previously higher level. This condition may indicate

that although chest compressions are adequate to circulate blood, the level of blood oxygen has diminished due to metabolism and additional oxygen delivery (accomplished by rescue breathing) is required to improve the victim's condition. Based upon detection of this set of conditions, the feedback control system will issue audible prompts

5 instructing the rescuer to stop compressions for a brief period and deliver one or several rescue breaths. The system will then prompt the rescuer to resume chest compressions as it monitors CPR, pulse and oxygen saturation parameters to estimate the success of CPR efforts and provide further prompts related to compression rate, depth and breathing.

Similarly, if the pulse oximetry sensor detects an increase from a lower level to a  
10 higher level of blood oxygen saturation in peripheral tissues during CPR, the feedback control system may determine that CPR is being effectively delivered. Under these conditions, the system will continue prompting the rescuer to maintain his/her rate and depth of chest compressions until the oxygen saturation plateaus and/or begins to decrease. When this occurs, the feedback system may (based upon detected compression  
15 rate, depth, pulse rate and blood oxygen saturation) prompt the rescuer to change his/her chest compression depth or rate or alternatively recommend the delivery of rescue breaths to the victim.

The system is designed as a feedback control system utilizing program logic (Figure 3), or linear and/or non-linear optimization techniques focused on maximizing the  
20 SpO2 as the cost function.

The CPR rate and depth measures can be used to ensure the control system remains within reasonable bounds based on predefined compression rate and depth ranges. These ranges are determined based on the established range for effective CPR.

Many other implementations of the invention other than those described above are  
25 within the invention, which is defined by the following claims. For example, other types of sensors could be used to provide SpO2 and pulse rate; each could be measured by a separate sensor. In some implementations, only one or the other of the parameters could be measured and used as the basis for feedback to the rescuer. The term SpO2 sensor has been used herein, but it should be understood that any sensor that provides a measure of  
30 blood oxygenation or pulmonary function is within what is meant by SpO2 sensor. Similarly, the pulse sensor can be any of various types that detect pulsatile movement of

blood in the circulatory system (e.g., pulse oximetry based pulse sensors, piezoelectric sensors, etc.) .

What is claimed is: